A Study of Effect of Various Process Parameters on Abrasive Jet Machining Using Silicon Carbide as Abrasive Material

Gaurav Mahajan
Final Year Undergraduate, Mechanical Engineering
RGIT, University of Mumbai, Mumbai, India

***Abstract*- Use of abrasive jet has been in existence for over twenty years, but it is yet to reach its full potential in the construction industry. Abrasive jets were introduced in the United States during the 1970's, and were utilized merely for cleaning purposes. As the technology developed to include abrasive jets, new applications were discovered. This paper deals with different experiments which were conducted to study the influence of abrasive jet machining (AJM) process parameters on material removal rate and diameter of holes of glass plates using silicon carbide abrasive particles. The experimental results of the present work are used to discuss the validity of proposed model as well as the other models. With the increase in stand tip distance (STD), the upper surface diameter and lower surface diameter of hole increases as it is in general observation of abrasive jet machining process. As the pressure increases, the material removal rate (MRR) is also increased.**

***Index Terms* - Abrasive jet machining, stand of distance, Material removal rate, Glass material**

I. INTRODUCTION

The glass and other brittle materials can be machined by non-conventional processes such as Ultrasonic Machining (USM), Abrasive Jet Machining (AJM), Electrical Discharge Machining (EDM), Electrochemical Machining (ECM), Laser Beam Machining (LBM) and Plasma Arc Machining (PAM). Abrasive Jet Machining has high degree of flexibility, and hence it is typically used for machining of glass and ceramic materials. Abrasive Jet Machining (AJM), also known as abrasive blasting, is a mechanical energy based non Traditional machining process used to remove unwanted material from a given work piece. The process makes use of an abrasive jet with high velocity, to remove material and provide smooth surface finish on hard work pieces. It is similar to Water Jet Machining [3] Manufacturers are trying to reduce the operation cost and increase the quality of products. The surface roughness and MRR are significant characteristics in machining of glass using AJM. There is a need to optimize the process parameters in a systematic way to achieve the output characteristics /responses by using experimental methods and statistical models

The literature study of Abrasive Jet Machine [1-11] states that the Machining process was started a few decades ago. Till date there has been a through and detailed experiment and theoretical study on the process. In recent years abrasive jet machining has been gaining increasing acceptability for deburring applications. The process of removal of burr and the generation of a convex edge were found to vary as a function of the parameters jet height and impingement angle, with a fixed SOD. The influence of other parameters, viz. Nozzle pressure, mixing ratio and abrasive size are insignificant. The SOD was found to be the most influential factor on the size of the radius generated at the edges. As the NTD increases the diameter of hole increases which is as shown in fig.1 [9]

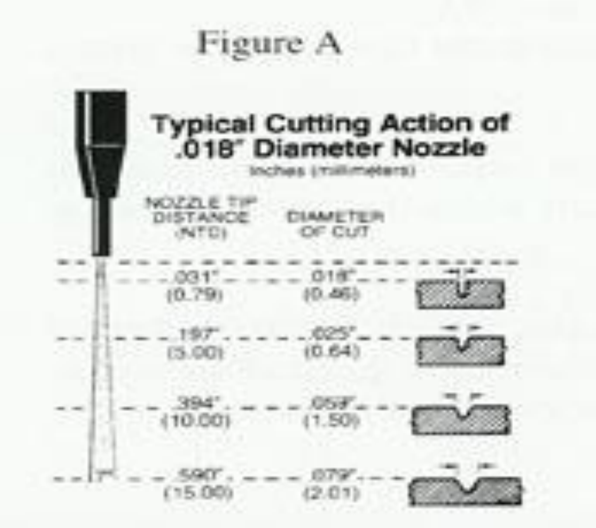


Figure 1 Effect of nozzle tip distance (NTD) on diameter of hole

Material removal rate (MRR) is ratio of volume of material removed from work piece to machining time. Chandra and Singh [8] have concluded that if nozzle tip distance (NTD) (mm) increases then MRR (mm^3/min) increases first then decreases as shown in figure

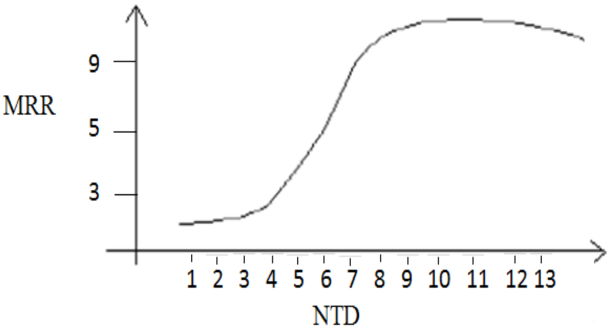


Figure 2 Relation between MRR & NTD

The effect of abrasive flow rate on material removal rate (MRR) is shown in Figure 3 [9] as the abrasive mass flow rate increases the material removal rate (MRR) increases which is also general observation in abrasive jet machining.

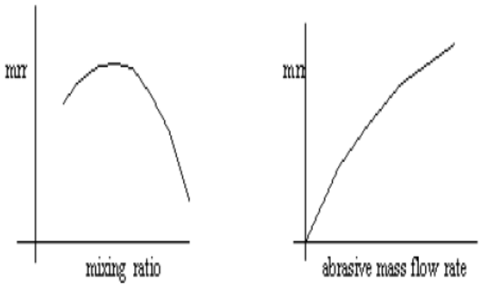


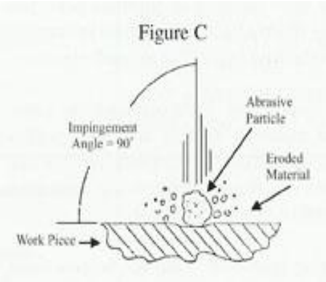
Figure 3 Effect of abrasive mass flow rate and mixing ratio on material removal rate (mrr)

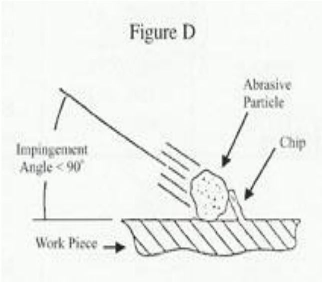
Angle of Contact

Simply, the angle with which you approach your surface with your nozzle will play a great role in determining the speed and efficiency of your work. There are two options to choose from. You can either approach your material directly by holding your nozzle at an angle of 90°, or you may approach your material at an angle by holding your nozzle at less than 90° and leaning to either the right or the left.

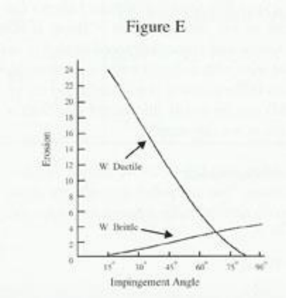
By choosing the first option, show in Figure C, you will be operating under the Theory of Brittle Failure. This theory describes that by holding your nozzle at 90°, "brittle failure" of your work surface will occur when the abrasive stream impacts it and literally blasts material out of way.

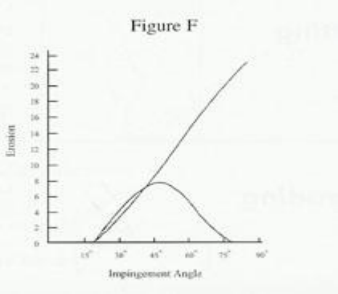
By choosing the second option, show in Figure D, you will be operating under the Theory of Ductile Failure. This theory describes that by holding your nozzle at an angle less than 90°, ductile failure of your work surface will occur as the abrasive stream steadily chips away at the material. [12,13]





Tests have shown that maximum material removal for ductile materials occurs between a 15 and 45 degree angle of incidence. For a brittle material, maximum removal occurs at an angle of 90 degrees. The figures below represent the comparative material removal rates for both hard and soft substances that have either brittle or ductile properties





In the present study the cutting variables were stand off distance of the nozzle from the work surface; work feed rate and pressure of jet. The evaluating criteria of the surface produced were width of cut , taper of the cut slot and work surface roughness. It has been observed that in order to minimize the width of cut; the nozzle should be placed closer to the work surface. Increase in pressure of jet results in widening of the cut slot both at the top and at exit of the jet from the work. However, the width of cut at the bottom (exit) was always found to be larger than that at the top. It was found that the taper of cut gradually decreases as the standoff distance incrases and was close to zero at the stand off distance of 4 mm. The jet pressure has no significant influence on the taper angle within the range of work feed and the stand off distance considered. Both stand off distance and the work feed rate show strong influence on the roughness of the machined surface. As the jet pressure increases the smoothness of wrok surface also increases..This is due to fragmentation of the abrasive particles into smaller sizes at a higher pressure and due to the fact that smaller particles produce smoother surface. So within the jet pressure considered, the work surface is smoother near the top surface and gradually it becomes rougher at higher depths. Drilling of glass has been carried out by M. Roopa Rani and S.Seshan [9]. The Roopa Rani and S.Seshan [9] results are used in the present work to compare the validation of my experimental work on abrasive jet machining.

II. EXPERIMENTAL SET UP AND PROCEDURE

Experiments were conducted on test rig. as shown in Fig.4. All results were compared with the results found in Roopa Rani [9] experimental work to check the validity of my results The experimentation was carried on a test rig. Present in the workshops of MU University,Mumbai, India. The abrasive particles (SiC) were mixed with air ahead of nozzle and the abrasive flow rate was kept constant throughout the machining process. The nozzle jet was made of tool steel to carry high wear resistance. Drilling of glass sheets was conducted by setting the test rig as shown in Fig. 4 on the parameters listed in Table1

TABLE 1 Abrasive Jet Machining Experimental Parameters

Sr. No	AJM Parameter	Condition
1	Type of abrasive	Silicion carbide
2	Abrasive size	80
3	Jet pressure	5-12 kg/cm2
4	Standoff distance	8-12.5

Here glass was used as a work piece material because of its homogeneous propertiess. The test specimens were taken in rectangular shape for machining on AJM unit having thickness 3mm, 4mm, 5mm, 6mm and 8mm. In machine the initial weights of glass specimens were measured with the help of digital balance. After machining the final weights were measured with the help of digital balance to calculate the material removal rate. First the silicion carbide abrasive is fed in the cylinder. After that compressor connections were checked. The glass specimen was properly clamped with the help of various clamps. As the compressor was switched on, the cylinder gate valve was opened so that abrasive particles were mixed with air jet coming from the compressor and focused on the specimen with help of nozzle. various readings were taken using different glass specimen with different thickness and all results were tabulated. All results were compared with the theoretical results also to check the validity of our results which were listed in the paper.

Figure 4. Abrasive Jet Machining Setup

Table 2 Abrasive jet machine characteristics

Carrier gas	Air , carbon –dioxide
Abrasives	Alumina , SiC
Pressure	2-10 atm
Nozzle	WC, sapphire
Critical parameters	Abrasive flow rate and velocity, nozzle tip distance abrasive grain size
Material application	Hard and brittle metals ,alloys, and non metallic
Nozzle life	12-300 S

TABLE 3 Various Process Parameters of AJM

SR.No	Process parameters
1	Carrier gas
2	Type of abrasive
3	Stand off distance
4	Abrasive size
5	Velocity
6	Mixing ratio
7	Shape of cut

III. EXPERIMENTAL RESULTS AND DISCUSSION

The following subsections detail the results of experiments that were conducted on test rig. as shown in Fig.4. The results of experiments were tabulated here. In our experiments first we changed the nozzle tip distance (NTD) and observed the effect of NTD on diameter of holes of work pieces. Secondly we changed the pressure of gas and observed its effect on material removal rate (MRR) of the work pieces. We had taken readings at different nozzle tip distance (NTD) and different pressures. After taking readings we plotted our results in the form of graphs here. The following graphs show the effect of nozzle tip distance (NTD) on diameter of holes of work pieces and effect of pressure on material removal rate (MRR).

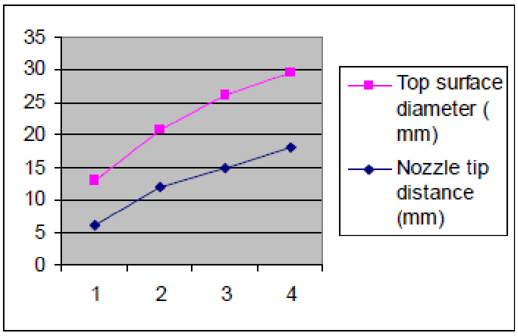


Figure 5 relationship between nozzle tip distance and top surface diameter of hole at a set pressure of 5.5 kg/ cm ^{2}

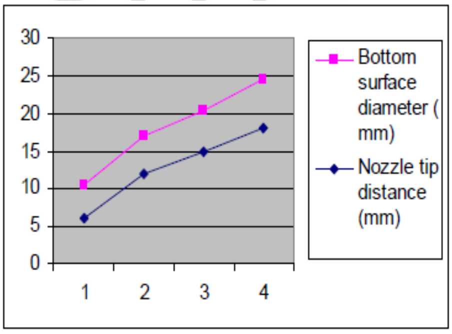


Figure 6 relationship between nozzle tip distance and bottom surface diameter of hole at a set pressure of 5.5 kg/ cm ^{2}

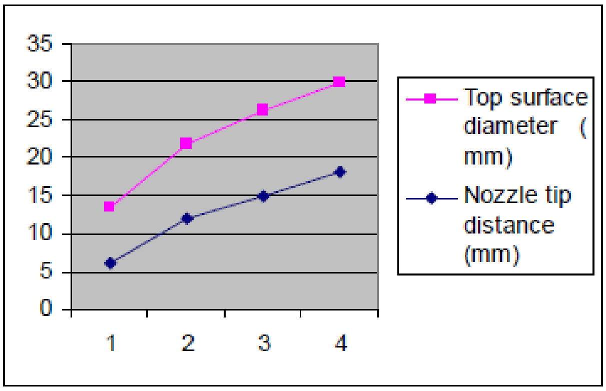


Figure 7 Relationship between nozzle tip distance and top surface diameter of hole at a set pressure6.5 kg/ cm^2

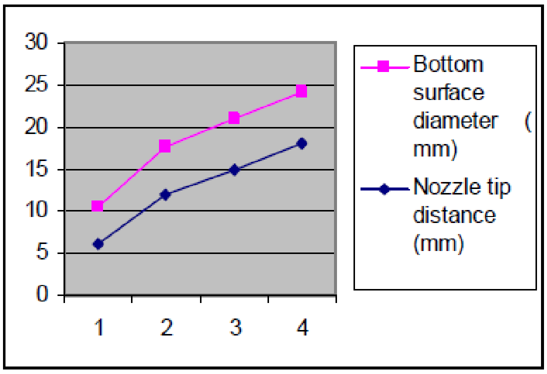


Figure 8. Relationship between nozzle tip distance and bottom surface diameter of hole at a set pressure6.5 kg/ cm^2

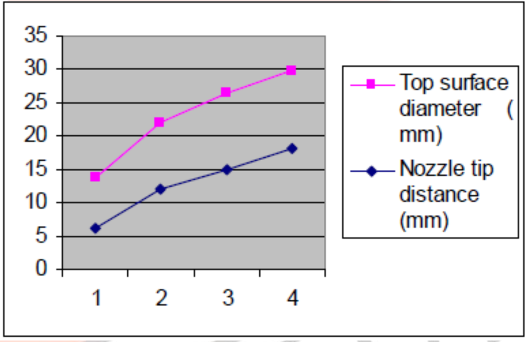


Figure 9 relationship between nozzle tip distance and top surface diameter of hole at a set pressure 7.5 kg/ cm^2

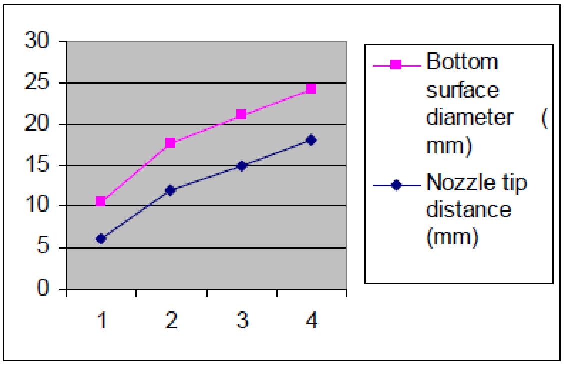


Figure 10 relationship between nozzle tip distance and bottom surface diameter of hole at a set pressure 7.5 kg/cm^2

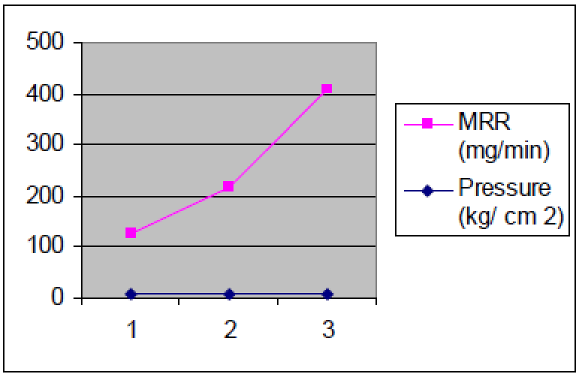


Figure 11 Relationship between pressure and material removal rate (MRR) at thickness 8 mm and NTD 12 mm

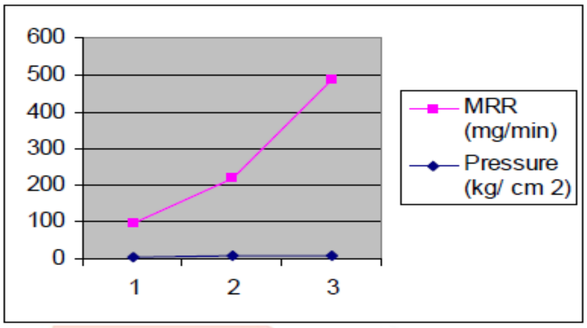


Figure 12 Relationship between pressure and material removal rate (MRR) at thickness 12 mm and NTD 12 mm

Results of experimental work by Roopa Rani and S.Seshan

These results were shown here in tables 9-10 and graphs (Fig.14-15) which shows the effect of pressure on the material removal rate and effect of NTD on diameter of hole in AJM process. Table 9 and Fig.14 shows the effect of pressure on material removal rate (MRR).

Table 9 Effect of pressure on material removal rate (MRR)

Sr.no	Gas pressure	MRR(mg/min)
1	5	18
2	6	21
3	7	23
4	8	26

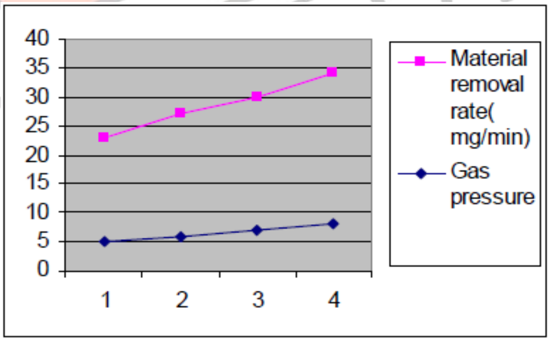


Figure 13 Relationship between pressure and material removal rate (MRR)

Table 10 and Fig.15 shows the effect of nozzle tip distance (NTD) on diameter of hole. As the distance between the face of nozzle and the working surface of the work increases, the diameter of hole also increases because higher the nozzle tip distance allows the jet to expand before impingement which may increase vulnerability to external drag from the surrounding environment. It is desirable to have a lower nozzle tip distance which may produce a smoother surface due to increased kinetic energy.

Table 10 Effect of NTD on diameter of hole

Sr no	Stand off distance	Diameter of hole
1	0.8	0.46
2	5	0.64
3	10	1.5
4	14	2

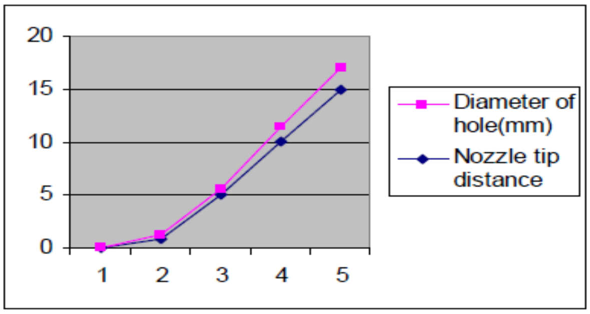


Figure 14 Relationship between NTD and diameter of hole

Small metal removal rates at a low NTD is due to a reduction in nozzle pressure with decreasing distance, whereas a drop in material removal rate at large NTD is due to a reduction in the jet velocity with increasing distance. So we have to select a optimum value of NTD to get maximum material removal rate in AJM process.

IV. CONCLUSION

This paper presents various results of experiments have been conducted by changing pressure, stand off distance on different thickness of glass plates. The effect of their process parameters on the material removal rate (MRR), top surface diameter and bottom surface diameter of hole obtained were measured and plotted. These were compared with the Standard results [9] and with it was observed that as nozzle tip distance increases, the top surface diameter and bottom surface diameter of hole increases as it is in the general observation in the abrasive jet machining process. As the pressure increases material removal rate (MRR) was also increased.

REFERENCES

[1] Hand book on “Non conventional machining”, Department of mechanical engineering, Version 2 ME, IIT Kharagpur, 2009.

[2] Jagadeesha T, “Non traditional machining”, Mechanical Engineering Department, National Institute of Technology, Calicut, chapter 35

[3] Shripad Chopade, Sagar Kauthalkar, and Pushpendra Kumar Sharma, “Abrasive Jet Machining”, International Journal of Modern Engineering Research (IJMER), Vol. 3, May-June 2013, pp-1504-1511

[4] M. Wakuda, Y. Yamauchi and S. Kanzaki “Effect of work piece properties on machinability in abrasive jet machining of ceramic materials”, Publication: Precision Engineering, Volume 26, Issue 2, April 2002, Pages 193-198

[5] R. Balasubramaniam, J. Krishnan and N. Ramakrishnan , “An experimental study on the abrasive jet deburring of cross drilled holes”, Publication: *Journal of Materials Processing Technology*, *Volume 91*, Issues 1-3, 30 June 1999, Pages 178-182

[6] R. Balasubramaniam, J. Krishnan and N. Ramakrishnan “A study on the shape of the surface generated by abrasive jet machining”, Publication: *Journal of Materials Processing Technology*, *Volume* 121, Issue 1, 14February 2002, Pages 102-106

[7] Alina Oancea, Lorelei Gherman, Laurentiu Slatineanu and Vasile Braha, **“**Modified nozzle for abrasive jet engraving”, Romanian Association of Nonconventional Technologies, June 2012,pp-16.

[8] Bhaskar Chandra Kandpal, Naveen Kumar, Rahul Kumar, Rahul Sharma and Sagar Deswal, “Machining of Glass and Ceramic with Alumina and Silicon Carbide in Abrasive Jet Machining”, International Journal of Advanced Engineering Technology, December 2011, pp-251

[9] M. Roopa Rani & S. Seshan “AJM - Procees Variables And Current Applications”, Publication- Journal of Metals Materials & Process,1995 Vol.7 No. 4 PP.279-290

[10] Neelesh K. Jain,V.K. Jain, K. Deb, “Optimization of process parameters of mechanical type advanced machining processes using genetic algorithm”, International Journal of Machine Tools and Manufacturer(2006).

[11] Sarkar, P.K., Pandey, P.C., “Some investigations on abrasive jet machining”, Journal of Inst. Eng.(56),1976.

[12] Deng Jianxin, Wu Fengfang and Zhao Jinlong, “Wear mechanism of Gradient Ceramic nozzles in Abrasive Air Jet machining”, International Journal of Machine Tools & Manufacture, 12 February 2007, pp-(2031-2033).

[13] A. Ghobeity, M. Papini and J.K. Spelt, “Abrasive jet micro-machining of planar areas and transitional slopes in glass using target oscillation”, Journal of Materials Processing Technology, 11 February 2009, pp-5123.